



Human-in-the-loop Simulation-based Combat Vehicle Duty Cycle Measurement: Duty Cycle Experiment 1 (06S-SIW-080)

Victor J. Paul
U.S. Army TARDEC-GVSL
April 4-5, 2006



Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 27 MAR 2006		2. REPORT TYPE Briefing Charts		3. DATES COVERED 13-12-2005 to 13-03-2006	
4. TITLE AND SUBTITLE Human-in-the-loop Simulation-based Combat Vehicle Duty Cycle Measurement: Duty Cycle Experiment 1 (06S-SIW-080)				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Victor Paul				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000				8. PERFORMING ORGANIZATION REPORT NUMBER #15662	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000				10. SPONSOR/MONITOR'S ACRONYM(S) TARDEC	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) #15662	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Briefing Charts					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 25	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline

- Duty Cycle Experiments
- Simulation Objectives
- Simulation Design
- Experiment Design
- Results
- Conclusions

Duty Cycle Experiments

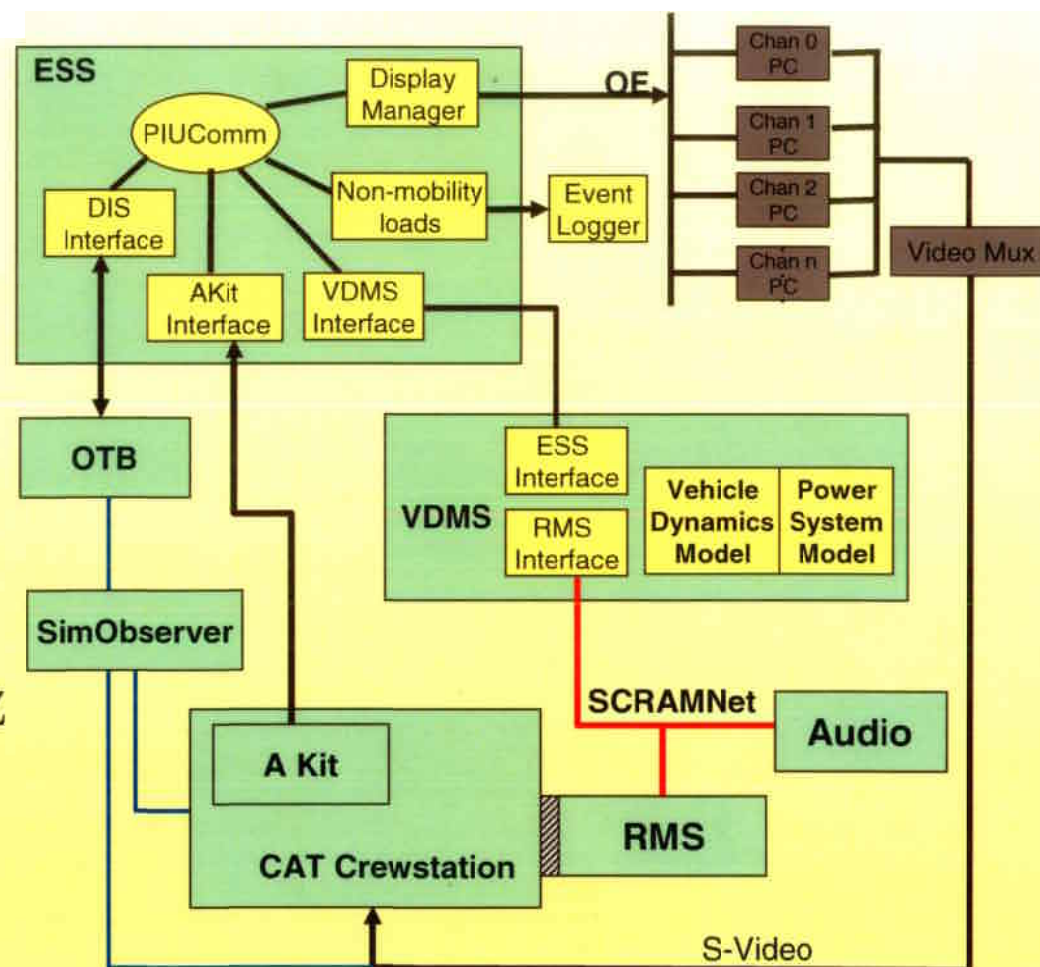
- TARDEC has a Power & Energy program to develop future vehicle power systems.
- Design requires understanding of use.
- To measure use, vehicle must exist.
- Duty cycle experiments use simulation to measure duty cycles of notional vehicles.
- Duty cycle captures:
 - Operator (driver/gunner) use
 - External events

Simulation Objectives

- Create motion based simulation to invoke realistic driving behaviors
- Measure power usage of modeled vehicle during simulated battle
 - Mobility Loads
 - Non-Mobility Loads
- Move towards hardware-in-the-loop experiment

Simulation Design: Top Level

- 6 Major Components
- 12 Computers
- Communications
 - Ethernet
 - SCRAMNet
- Performance:
 - Model update: 500 Hz
 - System Latency: 247 ms



Simulation Design: RMS

Platform Payload	1,600 lbs.
Platform Diameter	46 inches
Acceleration Bandwidth	40 Hz
Axes Displacement	
Linear (vert., lat., long.)	± 20 in.
Angular (roll, pitch, yaw)	$\pm 20^\circ$
Axes Velocity	
Linear (vert., lat., long.)	± 50 in./s
Angular (roll, pitch, yaw)	$\pm 70^\circ/\text{s}$
Axes Acceleration	
Linear (vert., lat., long.)	± 2 g's
Angular (roll, pitch, yaw)	$\pm 1150^\circ/\text{s}^2$



Applications

Man-in-the-loop simulation

Human/Robotic Investigations
Crew station design
HLA exercises/war-gaming

Crew station and component development

Seat characterization
Hardware component testing

Motion Drive

Washout Algorithms
Real-time Vehicle Dynamics
Control Loaders
Function Generator
Random Signal Generator

Data Acquisition

Soldier Performance
Vehicle Performance
HLA Battlefield Scenarios
Simulator Performance

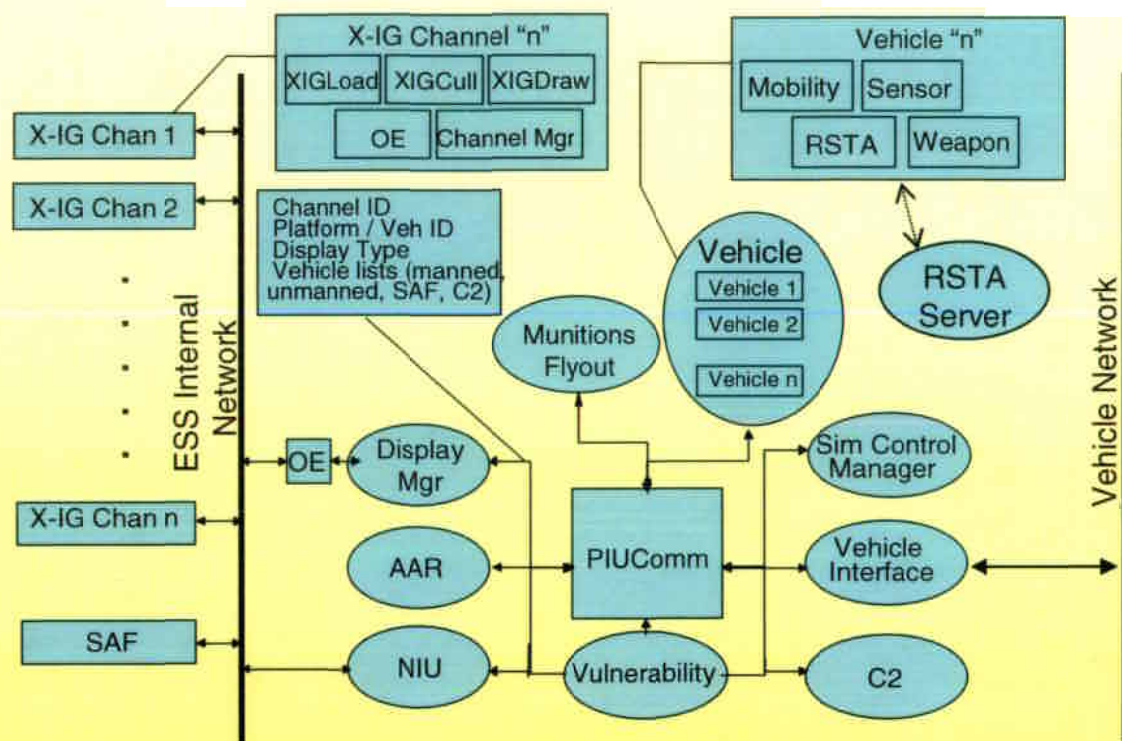
Simulation Design: CAT Crewstation

- Research tool for future crewstations
- 3 touch screens
 - 6 virtual displays
- Multi-function
- Soft button + hard button
- Yoke + Pedals
- “Drive” function



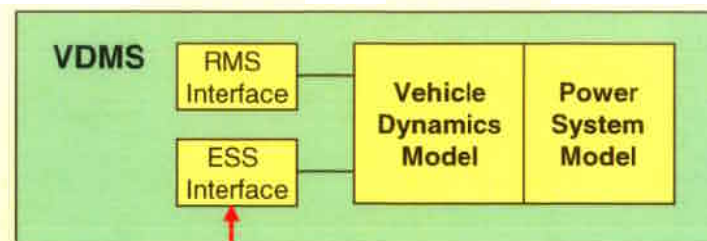
Simulation Design: ESS

- Provided with CAT
 - Training
 - Mission Rehearsal
- Used as DCE IG
- Based on open architecture
- Interfaces to OTB
- “Mobility” process replaced with VDMS

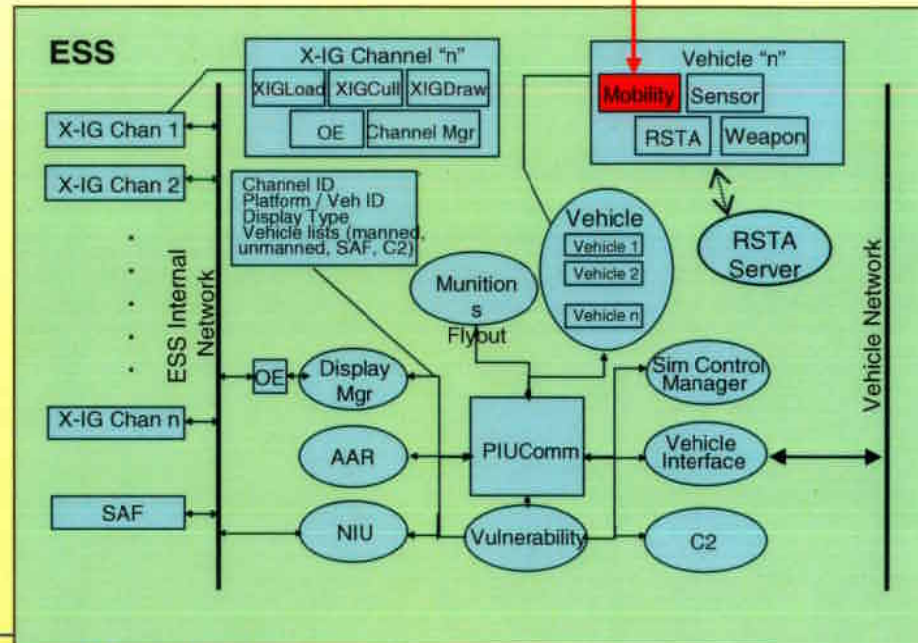


Simulation Design: VDMS

- VDMS is a process:
 - Real-time Dynamics
 - Power Train
 - Terrain Model
 - Interfaces to external systems.
- Deliver dynamic models in executable form.
- Can be used to simulate unmanned or manned vehicles.

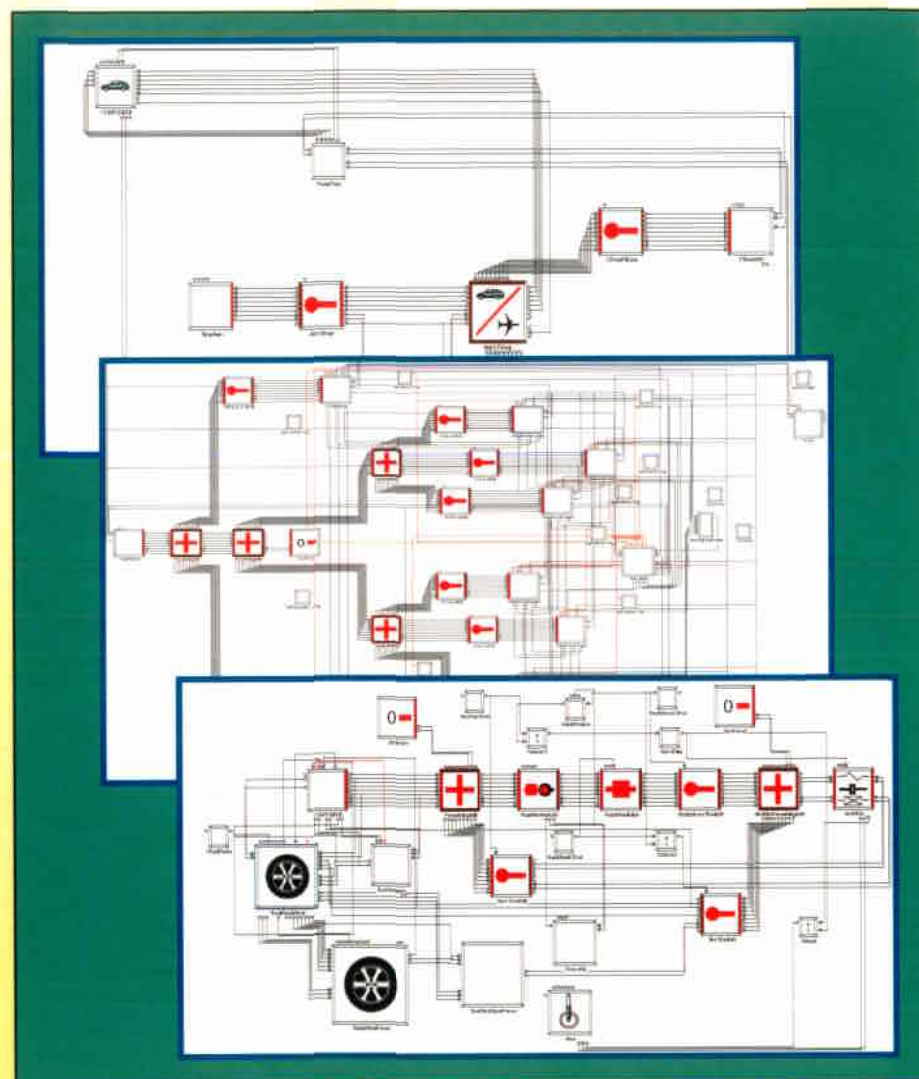


TCP/IP



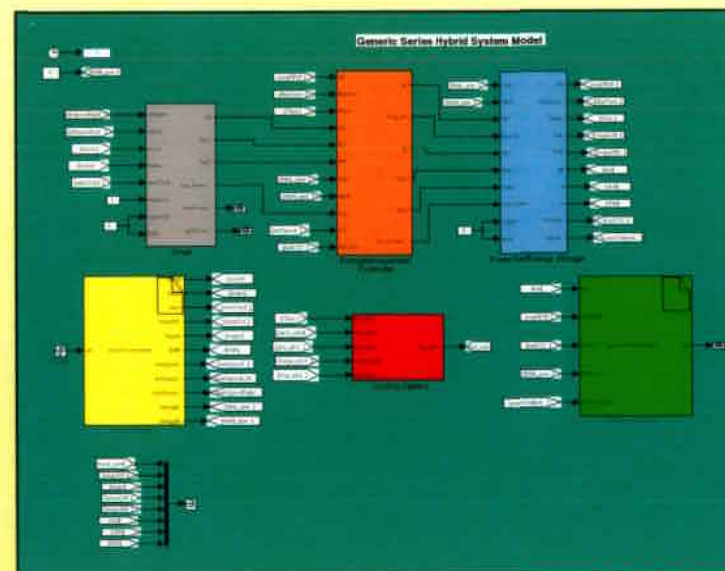
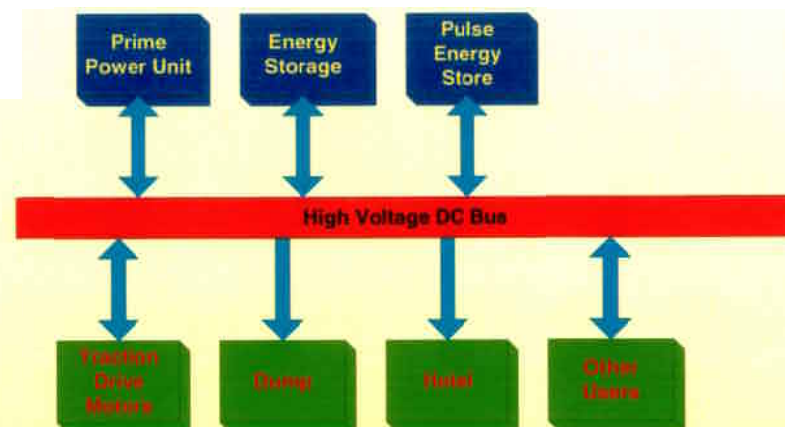
Simulation Design: Vehicle Dynamics

- 24T Tracked Vehicle (MCS)
- Front-drive
- 6 road wheels/side
- SimCreator®'s Multi-body Dynamics
- Executes in VDMS
- Interfaces to Power System



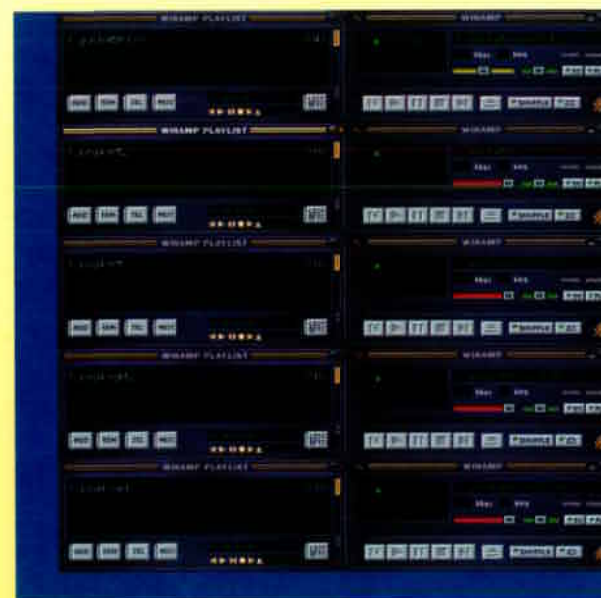
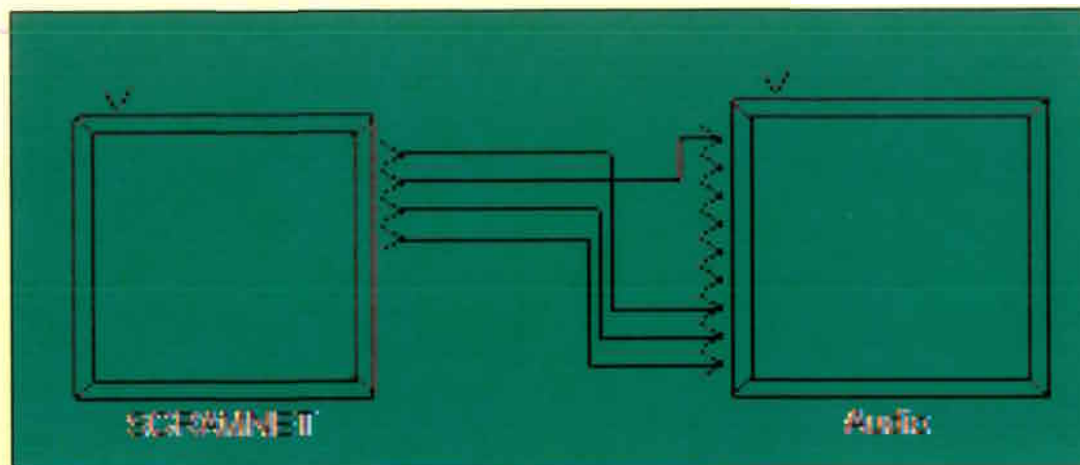
Simulation Design: Power System

- Series Hybrid Power System for MCS
- Independent Left/Right
- Diesel Engine/Generator
- 600 V bus w/Battery
- Two 300kW traction motors.
- Includes thermal model
- Implemented in Simulink w/ Real-time workshop



Simulation Design: Audio System

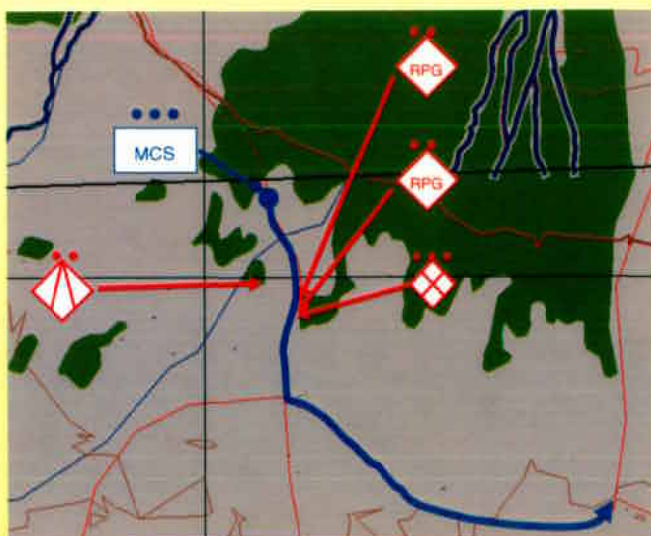
- Internal sounds
 - Engine
 - Track
 - Engine RPM & vehicle speed change sound
- External sounds
 - Battle noise
 - Bullet Pings



Experiment Design: Two Experiments

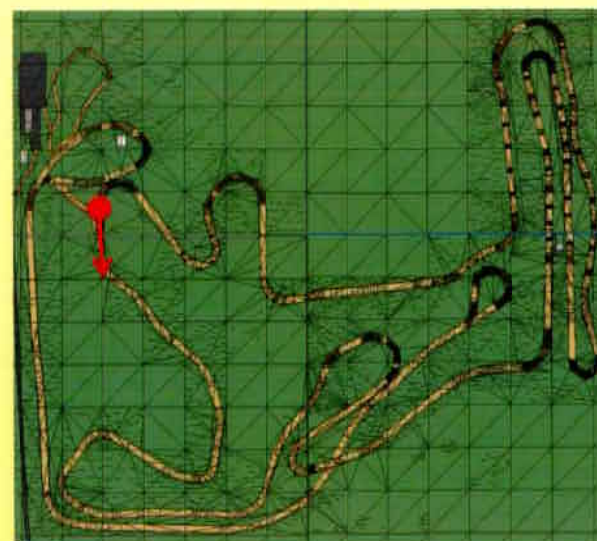
- DCE1

- Formal Study
- Battle scenario
- 9 civilian subjects



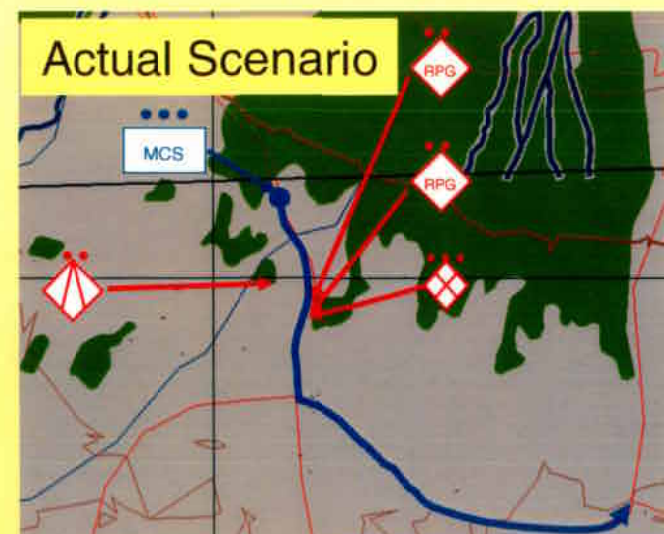
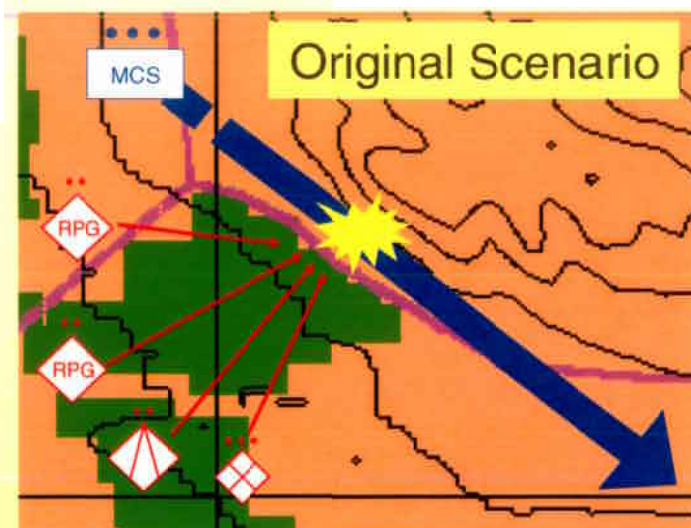
- DCE1.1

- Informal follow-on
- Driving scenario
- 7 civilian subjects



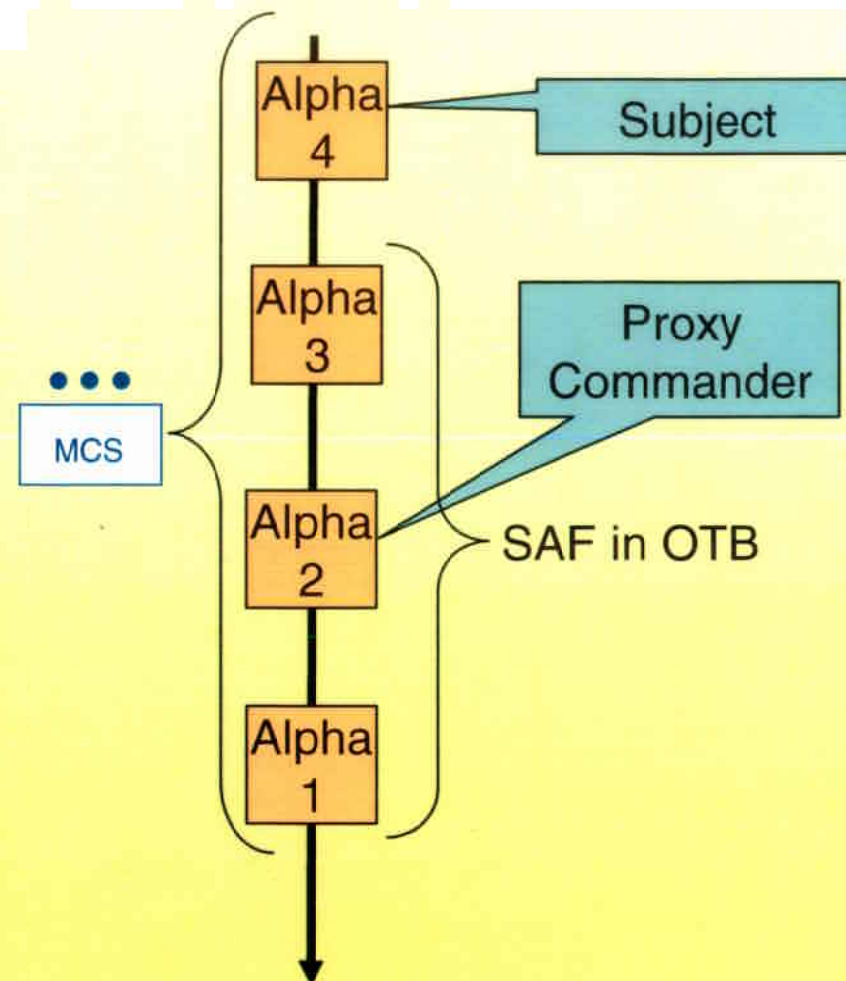
DCE1: Experiment Design

- Assess aggregate power consumption using CASTFOREM
- Extract vignette
 - 9 hours into battle
 - MCS PLT
 - Road March (12 km)
 - Dismount ambush
- Drive + defensive systems



DCE1: OTB Implementation

- Implemented in OTB 2.0
- Blue forces:
 - 3 SAF M1
 - “Alpha 1” – “Alpha 3”
 - 1 Virtual MCS
 - “Alpha 4”
- Red forces
 - RPG
 - ATGM



DCE1: Proxy Commander

- Serve as PLT leader
- Give direction
- Maintain “chatter”
- Give mission briefing
- Monitors OTB

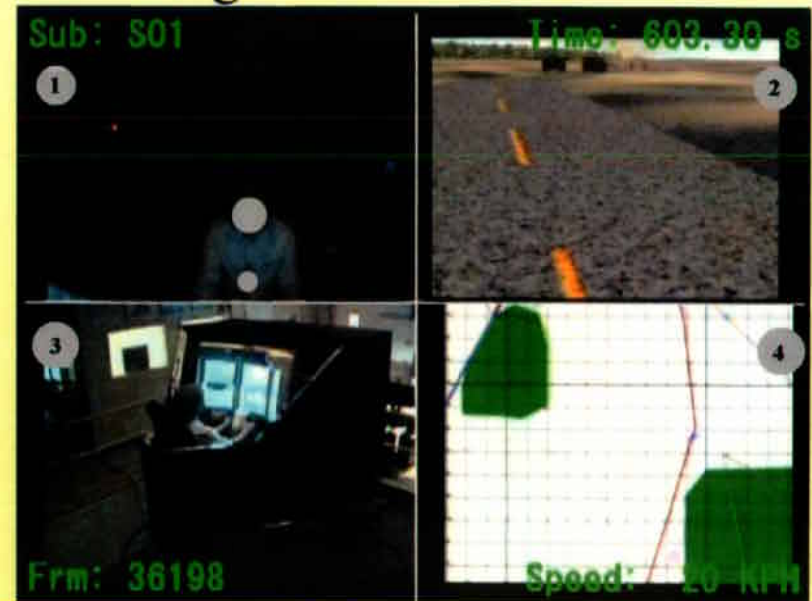
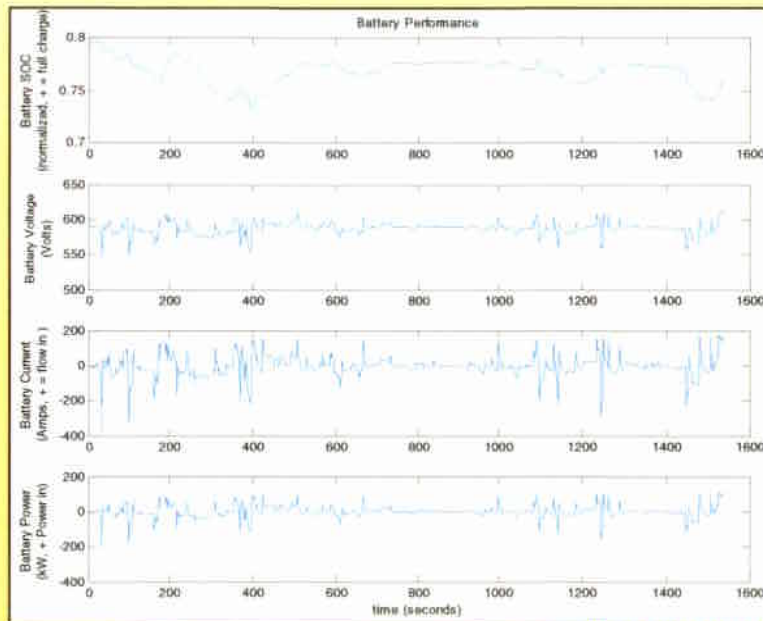


Voice



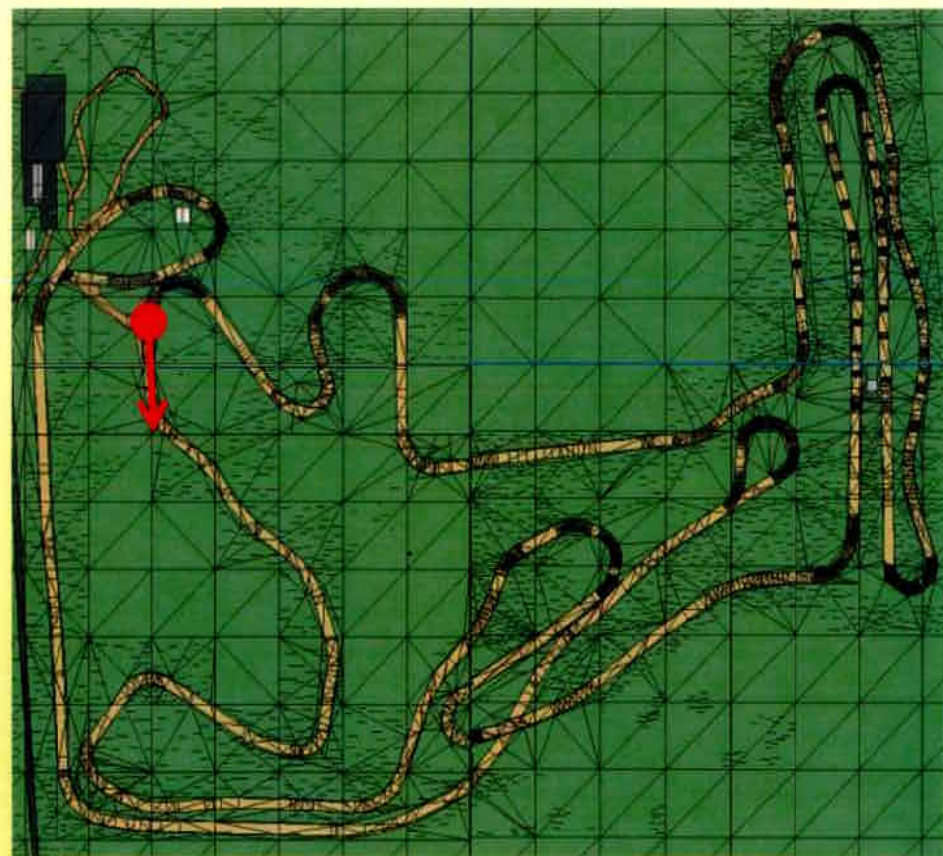
DCE1: Data Acquisition

- 57 channels of data at 100 Hz
 - 31 vehicle dynamics
 - 26 power system
- Video of experiment
- Events
 - hit,
 - transmission
- PDU log



DCE1.1: Experiment Design

- Drive one lap on hilly Army proving ground course.
- Record driver commands, speed, location.
- Seven subjects drawn from experimenters



DCE1: Subject Handling

- Affidavits and questionnaires
 - Consent form
 - Simulation Sickness Questionnaire (1 of 3)
 - Demographics Questionnaire
- Mission Briefing
- Practice drive
- Simulation Sickness Questionnaire (2 of 3)
- Conduct experiment
- Simulation Sickness Questionnaire (3 of 3)
- Exit Interview

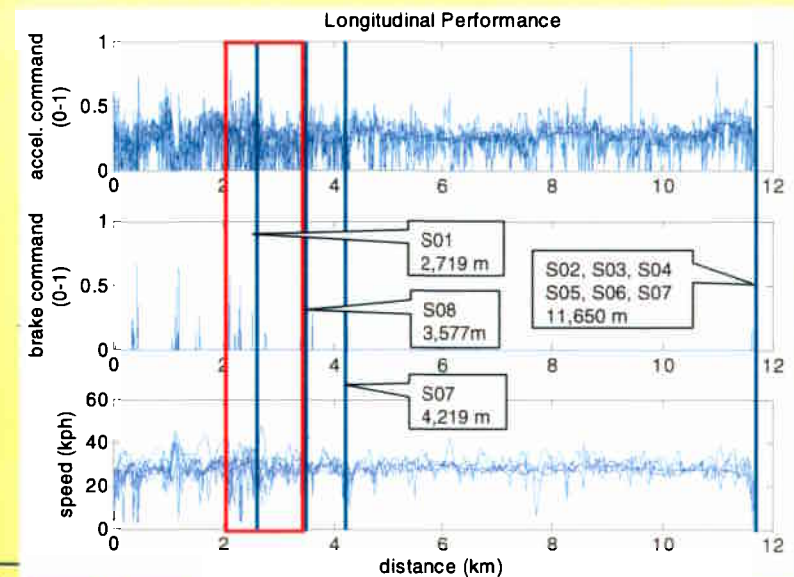
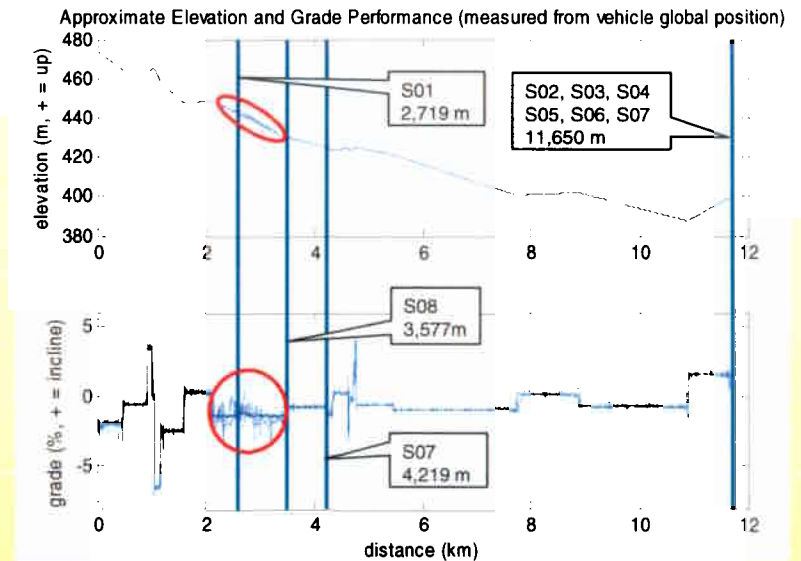
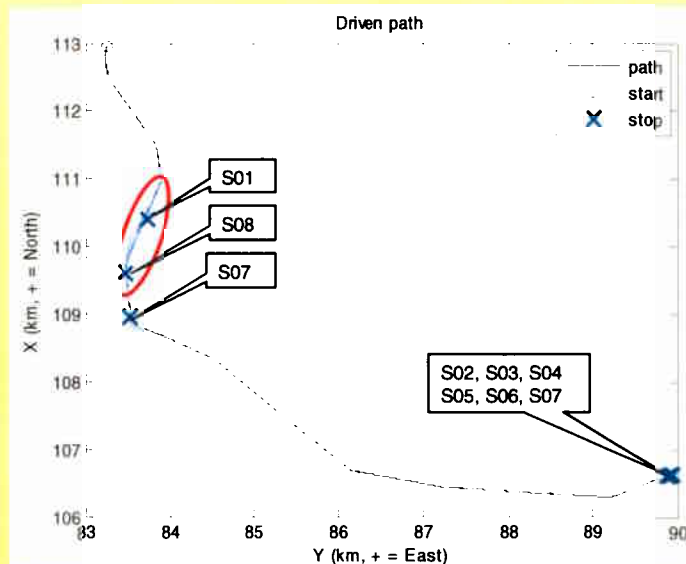
~ 2 hours

DCE1 Results: Demographics

- 9 Subjects (7 male, 2 female)
 - Age 29 ± 2.2 years
 - Education: $4.7 \text{ years} \pm 0.3 \text{ yrs}$ post HS.
 - Driving exp: $13 \pm 2.4 \text{ yrs}$.
 - Military vehicle exp: 5 subjects
 - None with tracked vehicle exp
 - Computer use: $46 \pm 7 \text{ hrs/wk}$.
 - Video game exp: $5.8 \pm 1.5 \text{ hrs/mo}$.

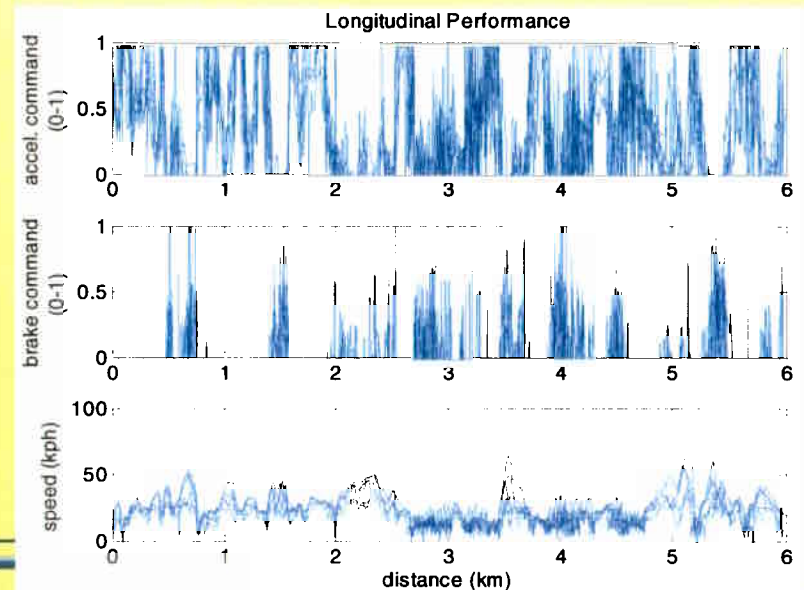
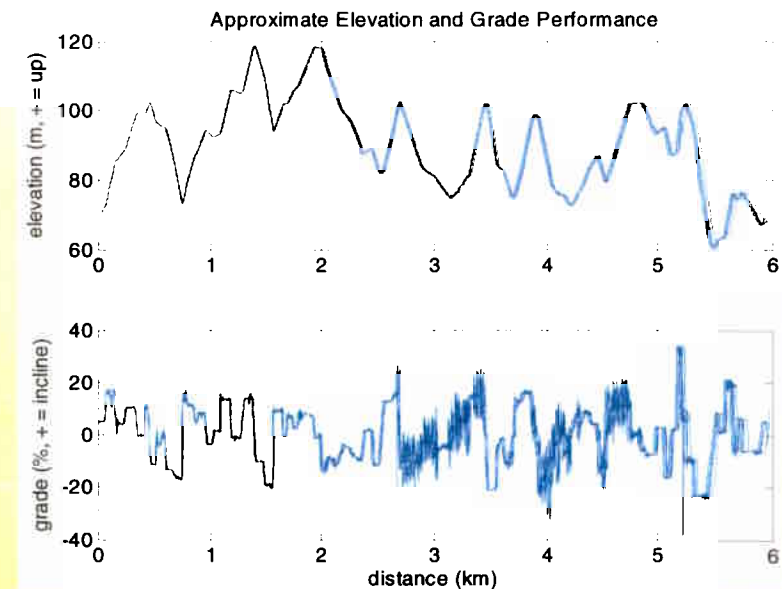
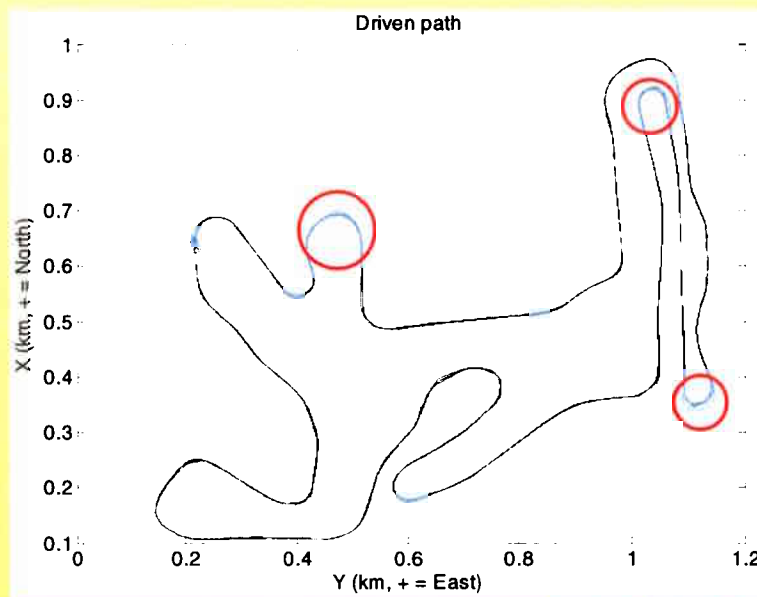
DCE1 Results: Duty cycle

- 6 subjects completed
- 3 ended early – computer crash
- No significant simulator sickness



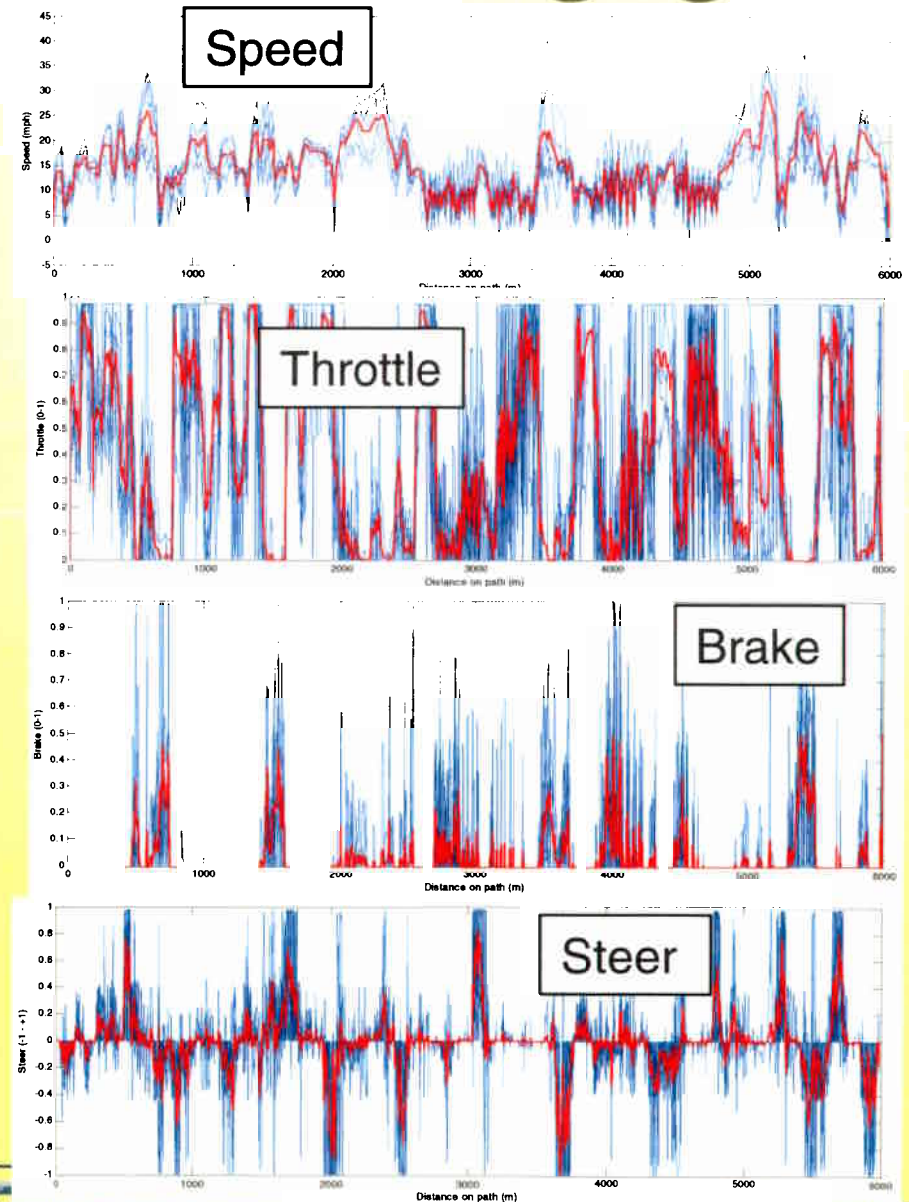
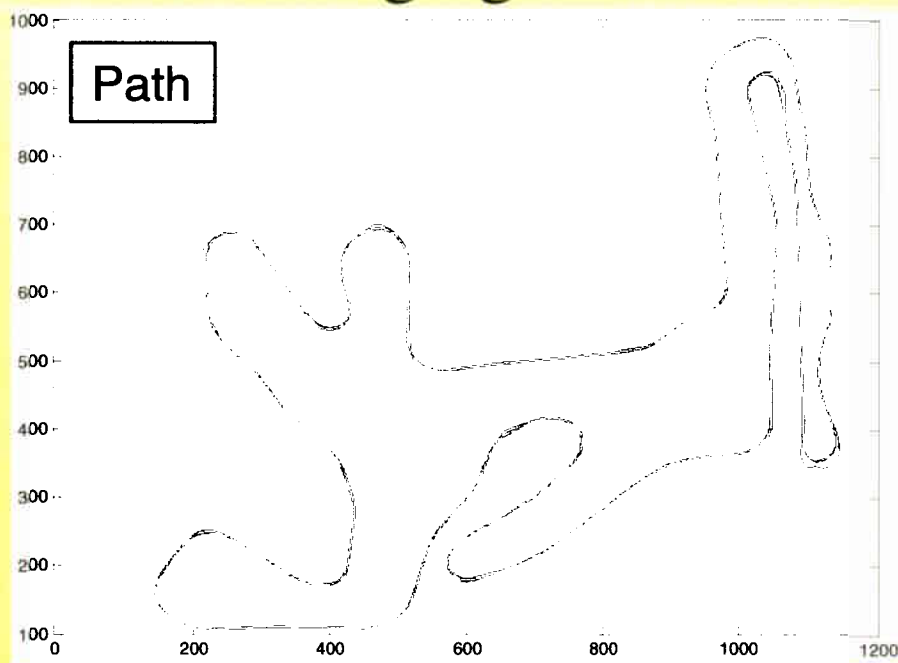
DCE1.1 Results: Duty cycle

- 7 subjects completed
- Lap times
–14.2 – 22.4 minutes
- Turns divergence



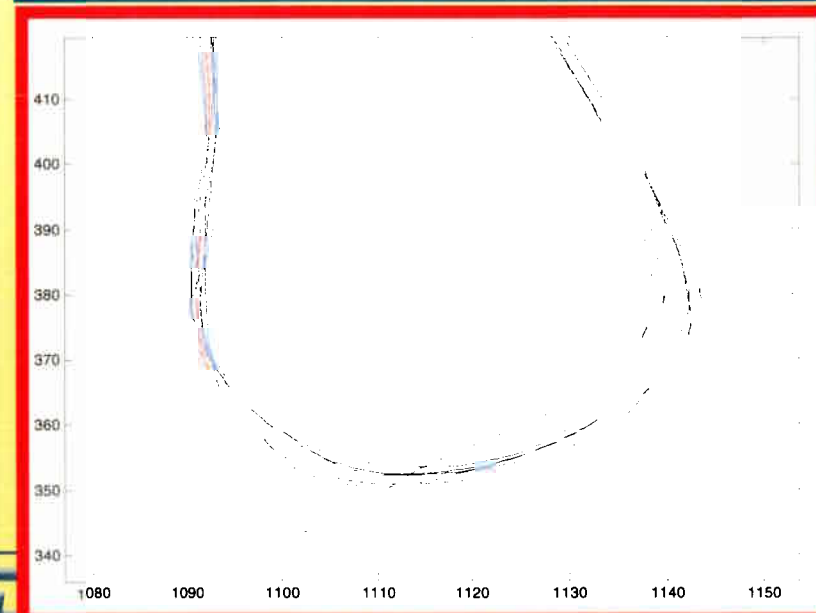
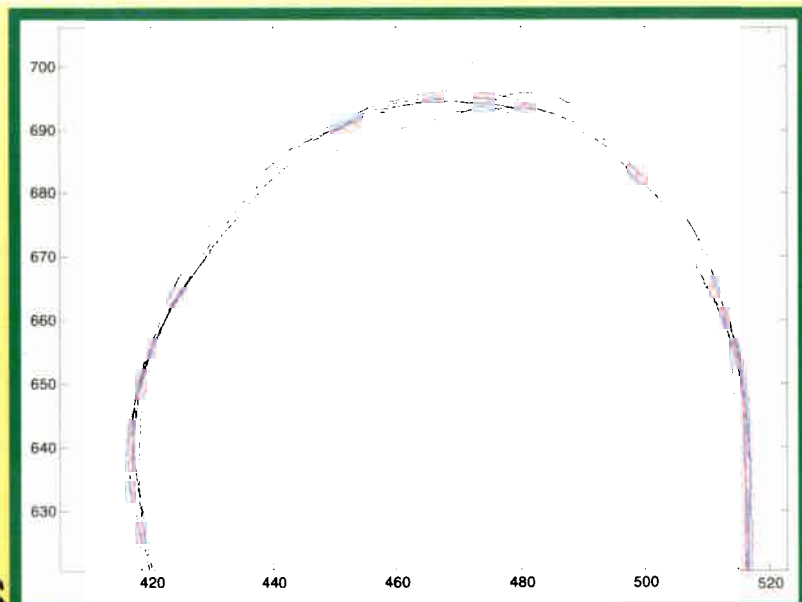
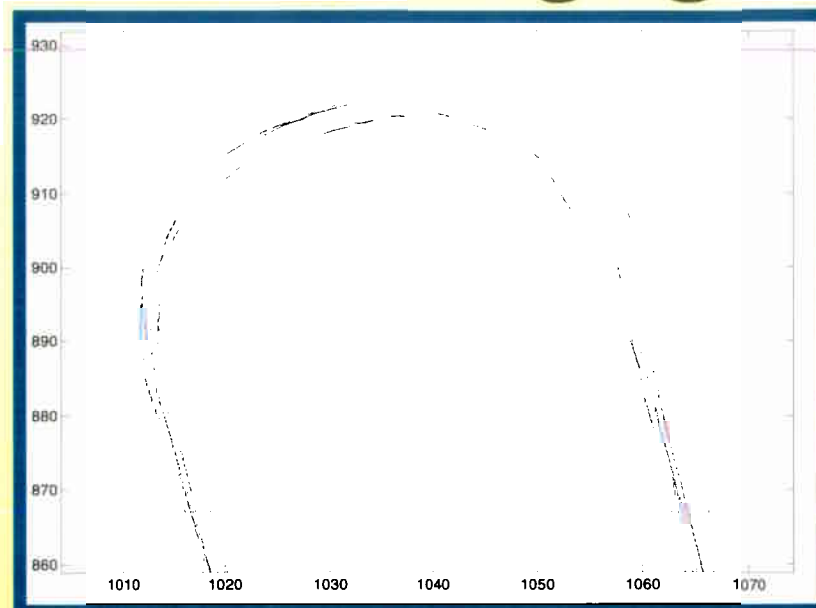
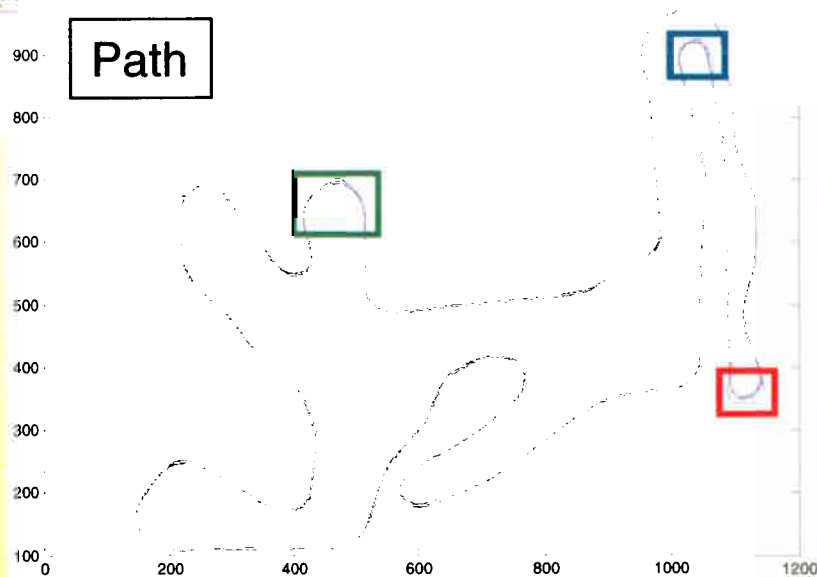
DCE1.1 Results: Path Averaging

- Find average path
- Synchronize data at each point.
- 2m averaging



DCE1.1 Results: Path Averaging

Path



Conclusions

- Two duty cycles were recorded.
 - Battle scenario with driving and defensive systems.
 - Power train evaluation course.
- Motion base simulation affects how a vehicle is operated.
- A scenario may be extracted from a force-on-force simulation and executed at a higher resolution.